

Name \_\_\_\_\_

AP Chemistry

## Atomic Mass/Molar Mass, Percent Composition, & Empirical and Molecular Formula

### *Atomic Mass/Molar Mass*

The mass for an element reported on the Periodic Table is the average mass of all the isotopes of that element. Today, the mass spectrometer can be used to determine the average atomic mass. It measures how much an atom deflects after being accelerated through an electric field; the heavier the atom the less it deflects. Based on this information, the mass spectrometer reports the masses and their abundances. Then the average atomic mass can be calculated. Furthermore, once these atomic masses are determined, the molar mass/formula weight of a compound can be calculated.

$$\text{Molar mass} = \text{Element 1} (x \text{ quantity}) + \text{Element 2} (x \text{ quantity}) \dots$$

### Example:

When a sample of natural copper is vaporized and injected into a mass spectrometer, the results below are obtained

Mass Number	Relative number of atoms
63	69.09
65	30.91

Use these data to compute the average mass of natural copper. (The mass values for  $^{63}\text{Cu}$  and  $^{65}\text{Cu}$  are 62.93 amu and 64.93 amu, respectively).

### Questions:

- 1) Calculate the average atomic mass for magnesium based on the data below:

Mass number	Exact weight	Percent abundance
24	23.985042	78.99
25	24.985837	10.00
26	25.982593	11.01

2) Calculate the average atomic mass for molybdenum:

Mass number	Exact weight	Percent abundance
92	91.906808	14.84
94	93.905085	9.25
95	94.905840	15.92
96	95.904678	16.68
97	96.906020	9.55
98	97.905406	24.13
100	99.907477	9.63

3) Uranium has three common isotopes. If the abundance of  $^{234}\text{U}$  is 0.01%, the abundance of  $^{235}\text{U}$  is 0.71%, and the abundance of  $^{238}\text{U}$  is 99.28%, what is the average atomic mass of uranium?

4) Determine the molar mass of the following compounds:

(a)  $\text{SO}_3$

(d) Sodium sulfate

(b)  $\text{CH}_3\text{COOH}$

(e) Ammonium nitrate

(c)  $\text{Cr}(\text{NO}_3)_3$

### *Percent Composition*

Throughout everyday life, there are compositions, such as with clothing or food. Particularly with candy such as M&Ms and Skittles, there is a mixture of colors in each individual bag. Percentages can be used to describe the different composition of colors. Percentage is also a useful tool in chemistry. The percent composition by mass of a compound represents the percent that each element in a compound contributes to the total mass of the compound. A chemist often compares the percent composition of an unknown compound with the percent composition calculated from the formula of a known compound. If the percentages agree it may confirm the identity of the unknown. Today you are going to calculate the percentage composition of each color in a random sample of Skittles and then review how to use it in chemistry.

Skittle Color	Number of Skittles	Percentage of Skittles
<b>Total</b>		

- 1) Identify the different colors in your sample of Skittles and write them in the first column.
- 2) Count the individual Skittles in each color and then sum them all to get the overall total.
- 3) Calculate the percentage of each color using the following formula:

$$\text{Percentage Composition} = \frac{\text{number of individual color}}{\text{total number}} \times 100\%$$

Now, change this formula to fit into chemistry:

$$\text{Percentage composition} = \frac{\text{_____}}{\text{_____}} \times 100$$

Questions:

- 1) Use the atomic masses of the elements to find the percent composition of hydrogen in H<sub>2</sub>O.
- 2) Arrange the following substances in order of increasing mass percent of carbon:  
C<sub>8</sub>H<sub>10</sub>N<sub>4</sub>O<sub>2</sub> (caffeine), C<sub>12</sub>H<sub>22</sub>O<sub>11</sub> (sucrose), C<sub>2</sub>H<sub>5</sub>OH (ethanol)
- 3) What is the percent composition of a compound that contains 8.1 grams of nickel and 2.2 grams of oxygen in a 10.3-gram sample?

- 4) Nicotine, the addictive drug in cigarettes, contains 74.0% carbon, 8.6% hydrogen, and 17.3% nitrogen. What mass of each element can be recovered from a 55.0-gram sample of nicotine?

### *Empirical Formula/Molecular Formula*

Based on the percent composition of a compound, the empirical formula can be determined. The empirical formula is the smallest-whole ratio between the elements. If the molar mass of the compound is known, then the molecular formula, which is the exact formula, can be calculated.

#### Example:

A white powder is analyzed and found to contain 43.64% phosphorous and 56.36% oxygen by mass. The compound has a molar mass of 283.88 g/mol. What are the compound's empirical and molecular formulas?

\*Assuming there is a 100 g of the sample, it would contain 43.64 g P and 53.36 g O.\*

Questions:

1) Give the empirical formula of each of the following compounds if a sample contains:

(a) 40.0% C, 6.7% H, and 53.3% O

(b) 11.66 g of iron and 5.01 g of oxygen

2) What is the molecular formula of each of the following:

(a) Empirical formula  $\text{HCO}_2$ , molar mass = 90.0 g/mol

(b) Empirical formula  $\text{C}_2\text{H}_4\text{O}$ , molar mass = 88 g/mol

3) Monosodium glutamate (MSG), a flavor enhancer in certain foods, contains 35.51% C, 4.77% H, 37.85% O, 8.29% N, and 13.60% Na and has a molar mass about 206 g/mol. Calculate the empirical and molecular formulas.